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Summary

On May 6, June 25-27, 1992, and February 9, 1993, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at engine houses 1, 2, and 3 of the Division of Fire in Lancaster, Ohio. This HHE was performed in response to a joint request from the Division of Fire and the International Association of Firefighters Local 291 to evaluate exposure to diesel exhaust emissions in the engine houses.

On May 6, 1992, NIOSH investigators performed a walk-through survey of the three engine houses in order to formulate a sampling strategy. Air samples for components of diesel exhaust emissions were collected on the evening through early morning of June 25-26 and again on the evening through early morning of June 26-27, 1992, to evaluate exposures during a typically busy shift. On February 9, 1993, NIOSH investigators visited the engine houses again to obtain data used to formulate the recommendations regarding engineering controls contained in this report.

Personal breathing zone (PBZ) air samples for elemental carbon, a surrogate for diesel exhaust, were collected at all three engine houses. General Area (GA) air samples for elemental carbon, carbon monoxide (CO), benzene-solubles, and nitrogen dioxide (NO_2) were collected at all three engine houses. In addition, a GA air sample for elemental carbon was collected outside each engine house and away from sources of diesel emissions, to measure the concentration of ambient elemental carbon.

The elemental carbon results are presented in Tables 1-4. In Engine House 1, PBZ samples ranged from 51.7 to 71.2 micrograms per cubic meter (µg/m^3) on the first night. On the second night of sampling, June 26-27, the results of PBZ samples for elemental carbon in Engine House 1 ranged from 14.1 to 21.2 µg/m^3. PBZ samples in Engine House 2 ranged from 25.7 to 38.1 µg/m^3 on the night of June 25-26. On the night of June 26-27, the results of PBZ samples for elemental carbon in Engine House 2 ranged from 19.8 to 78.8 µg/m^3. On the night of June 25-26, the results of PBZ samples collected in Engine House 3 ranged from 24.0 to 35.2 µg/m^3. On the second night of sampling, June 26-27, the results of PBZ samples collected for elemental carbon ranged from 48.0 to 60.5 µg/m^3. The average background elemental carbon concentration measured on the first night of sampling was 12.1 µg/m^3. The average background elemental carbon concentration measured on the second night of sampling was 8.4 µg/m^3.

When diesel-powered equipment leaves or returns to an engine house, exhaust emissions containing diesel particulate are produced inside the apparatus bay. The diesel exhaust can enter the living quarters and be breathed by the firefighters. Limited epidemiological evidence suggests an association between occupational exposure to diesel exhaust emissions and lung cancer. Engineering controls and work practices to reduce the potential risk to firefighters from diesel exhaust emission exposures are presented in the recommendations section of this report

KEYWORDS: SIC 9224 (Fire Protection), Firefighters, diesel, elemental carbon, benzene solubles, carbon monoxide, nitrogen dioxide

Introduction

On May 6, June 25-27, 1992, and February 9, 1993, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at engine houses 1, 2, and 3 of the Division of Fire in Lancaster, Ohio. This HHE was performed in response to a joint request from the Division of Fire and the International Association of Firefighters Local 291 to evaluate exposure to diesel exhaust emissions in the engine houses. NIOSH received the request on February 24, 1992.

Background

At the time of the survey, the Lancaster Division of Fire was comprised of 77 uniformed employees working in three engine houses and two secretaries. Firefighters worked a 24-hour shift, followed by 48 hours off duty. Engine House 1 was built in 1897, with an addition, including an additional apparatus floor, built in 1969. Three diesel-powered vehicles were housed in the old apparatus bay, including two fire engines and a medic vehicle. Two reserve trucks were housed on the new apparatus floor at the time of this report. One of these trucks was diesel-powered. Engine House 2, built in 1954, housed a diesel-powered medic unit, a diesel-powered fire engine, and a gasoline-powered brush truck. Engine House 3, built in 1966, housed two diesel-powered vehicles; a medic unit and a fire engine, in addition to a reserve aerial unit with a gasoline engine. None of the three engine houses had any mechanical ventilation system designed to remove vehicle emissions. The Division of Fire responds within the city limits of Lancaster, Ohio, a city with a population of approximately 36,000. During the opening conference on May 6, 1992, Thursday evening through Friday morning, and Friday evening through Saturday morning were identified as busy periods. All of the diesel-powered vehicles have their tailpipes located underneath the vehicle, on the right side. On medic units, the tailpipe is located behind the rear wheels. On fire engines, it is located between the back of the cab and the rear wheels. Figures 1-4 are floor plans of the three engine houses. These figures illustrate the relationship between the apparatus floors and the living quarters in each engine house.

Materials and Methods

On May 6, 1992, NIOSH investigators performed a walk-through survey of the three engine houses in order to formulate a sampling strategy. Air samples for components of diesel exhaust emissions were collected on the evenings through early mornings of June 25-26 and June 26-27, 1992, to evaluate exposures during typically busy periods. Sampling times represent approximately half of each 24-hour shift. Samples were collected with the engine houses' garage doors closed unless a vehicle was departing or returning.

Personal breathing zone (PBZ) air samples for elemental carbon were collected at all three engine houses. At each engine house, samples were collected in the breathing zones of an officer and two other employees (either fire fighters, medic/fire fighters, medics, or medic trainees). In order to evaluate just the exposures that occurred in the engine houses, rather than that which occurred while riding the emergency vehicles, employees were asked to turn off the sampling pumps when the vehicle in which they were riding cleared the engine house doors and turn the pumps on when the vehicle began backing into the engine house upon their return. In this way, potential exposures were evaluated when the emergency vehicles' engines were started, and when the vehicles reentered the garage. NIOSH investigators permitted employees to place the sampling devices near their bunks when the employees went to sleep.

General Area (GA) air samples for elemental carbon, carbon monoxide (CO), benzene-solubles, and nitrogen dioxide were collected at all three engine houses. Sampling locations are presented in Figures 1-4. In addition, a GA air sample for elemental carbon was collected outside each engine house and away from sources of diesel emissions, to measure the concentration of ambient elemental carbon.

Elemental carbon samples were collected and analyzed using the thermal-optical method (TOM). The TOM is an evolved gas technique wherein speciation of organic, carbonate, and elemental carbon is accomplished through temperature/atmosphere control and optical measurements.[1] Samples were collected on 37-millimeter (mm) diameter, quartz-fiber filters supported on stainless steel screens in open-faced cassettes. The filters were pre-fired in a plasma furnace prior to sampling to remove any carbonaceous contaminants. Each cassette used to collect a sample was connected via Tygon tubing to a battery-powered personal sampling pump, calibrated before sampling to a flow rate of 2 liters per minute (L/min). The flow rate was checked at intervals throughout the shift and at the end of the sampling period. The final flow rate was averaged with the initial flow rate and multiplied by the sampling time to derive the volume of air sampled. At the contract laboratory, one-square centimeter (cm^2) punches were taken from the filters for analysis.

The TOM analysis involves three operational stages. First, organic and carbonate carbon are volatilized from the quartz filter punch in a helium atmosphere as the sample oven's temperature is stepped to 680°C. Evolved carbon is catalytically oxidized to carbon dioxide and subsequently reduced to methane, which is quantified by a flame ionization detector. Temperature steps were chosen such that carbonate carbon appears as the fourth of four peaks typically observed in the thermogram (a plot of detector response versus temperature). The second stage of the analysis begins after reducing the oven temperature to 525°C. At this point, an oxygen-helium mix is introduced and the oven temperature is raised to 750°C. It is during this stage that pyrolysis correction and elemental carbon measurement are made. An optical feature corrects for pyrolytically generated elemental carbon, or "char" formed during the analysis. In the final stage of the analysis, calibration is achieved by injecting a known quantity of methane into the oven.[1]

GA air samples for nitrogen dioxide were collected using Palmes Tubes and analyzed by visible spectroscopy according to NIOSH method 6700.[2] GA air samples for benzene-solubles were collected and analyzed using a modified version of NIOSH method 5023.[2] Samples were collected on 37-mm diameter Zefluor filters in closed-faced cassettes connected via Tygon tubing to battery-powered sampling pumps pre- and post-calibrated to operate at a flow rate of 2 L/min. At the contract laboratory, the samples were placed in screw-cap vials with 5 milliliters (ml) of benzene and then sonicated for 30 minutes. The extract was filtered through a 0.5 micron (µm) Teflon filter and collected in an additional test tube. One ml of each sample was then transferred into a tared Teflon cup and evaporated to dryness in a vacuum oven at 40°C. The Teflon cups were weighed again, and the difference from the tare weight recorded. The weight gain of the cup was then equal to one-fifth of the total benzene-solubles per sample. The limit of detection for this sample set was 0.05 mg of benzene solubles per sample, which is based upon the precision of the balance used to weigh the samples.

GA air samples for carbon monoxide were collected using direct-reading colorimetric diffusion tubes. Carbon monoxide gas which diffuses into the tube reacts with a palladium compound to produce a color change from light-yellow to grayish-black. The length of the stain is the product of the concentration of carbon monoxide and the sampling time. Dividing this product by the sampling time yields a time-weighted average exposure concentration. The manufacturer reports that the range of measurement for these tubes is 50 to 600 ppm hours, or 3.6 ppm as the lower limit for a maximum sampling time of 822 minutes in this sample set. Results less than this amount should be regarded as trace concentrations, with limited confidence in their accuracy.

Finally, colorimetric indicator tubes were used to evaluate short-term exposures to carbon monoxide, sulfur dioxide, nitrogen dioxide, and total oxides of nitrogen when the NIOSH investigators were at an engine house while the emergency vehicles there responded to alarms.

Evaluation Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed from eight to ten hours a day, forty hours a week, for a working lifetime without experiencing adverse health effects. However, it is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled to the level set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, thus potentially increasing the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the US Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), and 3) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs).[3,4,5] The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; in contrast, the NIOSH-recommended exposure limits are primarily based upon the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing those levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA PEL.

A time-weighted average exposure level (TWA) refers to the average airborne concentration of a substance during a normal eight to ten hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from brief high exposures.

<u>Diesel Exhaust Emissions</u>

Diesel engines function by facilitating the combustion of liquid fuel without spark ignition. Air is compressed in the combustion chamber, fuel is introduced, and ignition is accomplished by the heat of compression.

The emissions from diesel engines consist of a complex mixture, including gaseous and particulate fractions. The composition of the mixture varies greatly with fuel and engine type, load cycle, maintenance, tuning, and exhaust gas treatment. The gaseous constituents include carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, oxides of sulfur, and hydrocarbons (e.g., ethylene, formaldehyde, methane, benzene, phenol, 1,3-butadiene, acrolein, and polynuclear aromatic hydrocarbons).[6,7,8,9] The particulate fraction (soot) is composed of solid carbon cores, produced during the combustion process, which tend to combine to form chains of particles or aggregates, the largest of which are in the respirable range (more than 95% are less than 1 micron in size).[10] Estimates indicate that as many as 18,000 different substances resulting from the combustion process may be adsorbed onto these particulates.[11] The adsorbed material contains 15 - 65% of the total particulate mass and includes such compounds as polynuclear aromatic hydrocarbons, a number of which are known mutagens and carcinogens.[9,10,12]

Many of the individual components of diesel exhaust are known to have toxic effects. The following health effects have been associated with some of the components of diesel exhaust emissions: 1) pulmonary irritation from oxides of nitrogen 2) irritation of the eyes and mucous membranes from sulfur dioxide, phenol, sulfuric acid, sulfate aerosols, and acrolein; and 3) cancer in animals from polynuclear aromatic hydrocarbons.

Several recent studies confirm an association between exposure to whole diesel exhaust and cancer in rats and mice.[13] The lung has been identified as the primary site of carcinogenic or tumorigenic responses following inhalation exposure. Limited epidemiological evidence suggests an association between occupational exposure to diesel exhaust emissions and lung cancer.[13] The agreement of current toxicological and epidemiological evidence suggests that occupational exposure to diesel exhaust is a potential carcinogen.[10] Tumor induction is associated with diesel exhaust particulates, and limited evidence suggests that the gaseous fraction of diesel exhaust may be carcinogenic as well.[10]

NIOSH recommends that whole diesel exhaust be regarded as a "potential occupational carcinogen," as defined in the Cancer Policy of the Occupational Safety and Health Administration (OSHA) ("Identification, Classification, and Regulation of Potential Occupational Carcinogens," 29 CFR 1990). This recommendation is based on findings of carcinogenic and tumorigenic responses in rats and mice exposed to whole diesel exhaust. Though the excess risk of cancer in diesel-exhaust-exposed workers has not been quantitatively estimated, it is logical to assume that reductions in exposure to diesel exhaust in the workplace would reduce the excess risk.[10]

Elemental Carbon

NIOSH researchers have selected the use of elemental carbon as a surrogate measure of exposure to particulate diesel exhaust because it is more sensitive than the gravimetric approach.[1] Selection of elemental carbon as a marker for diesel exhaust exposure was based upon research which evaluated a number of species as indices of overall diesel exposure.[1] Included in that evaluation were carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, total and fine particulate material (determined gravimetrically), volatilizable carbon (organic) and elemental carbon. Of these constituents of diesel exhaust emissions, elemental carbon was the most reliable measure of "diesel exhaust as an entity."[1] That is, it reflected exposures to the largest number of exhaust components studied.[1] Elemental carbon constitutes a large portion of the diesel particulate mass, serves as a carrier of polycyclic aromatic compounds, can be quantified at low levels, and the diesel engine is its only significant source in many workplaces.[1]

Benzene-Solubles

Concentrations of polynuclear aromatic hydrocarbons can be determined by using solvents such as benzene to extract these and other compounds from samples of airborne particulate.[10] This analysis yields the solvent-soluble portion of the particulates (referred to here as benzene-solubles), which can be further fractionated.[10] The benzene-soluble method is non-specific; it simply measures gravimetrically the benzene-soluble portion of sampled particulate matter.[2] This method is often used as another index of exposure to the particulate fraction of diesel-exhaust emissions.[2] The same sampling method has been used to gauge worker exposures to solvent solubles from other sources, including coal tar pitch volatiles, which are encountered around coke ovens; and petroleum asphalt fume.[2] However, coal tar pitch volatiles and the solvent-soluble particulate portion of petroleum asphalt fume are not equivalent to the benzene-soluble portion of diesel exhaust emissions. While they all contain polynuclear aromatic hydrocarbons, these compounds are present in a lesser degree in diesel exhaust emissions than in coal tar pitch volatiles. Therefore, occupational exposure limits to coal tar pitch volatiles are not applicable to the benzene-soluble portion of diesel exhaust emissions.

Nitrogen Dioxide

Nitrogen dioxide is a respiratory irritant; it causes pulmonary edema.[14] Humans exposed to nitrogen dioxide for one hour can expect the following health effects: 100 ppm, pulmonary edema and death; 50 ppm, pulmonary edema with possible subacute or chronic lesions in the lungs; and 25 ppm, respiratory irritation and chest pain.[14] A concentration of 50 ppm is moderately irritating to the eyes and nose.[14] The NIOSH REL for nitrogen dioxide is 1 ppm as a 15 minute STEL.[3] The current OSHA permissible exposure limit (PEL) for nitrogen dioxide is 5 ppm as a ceiling, a value never to be exceeded during the workday.[4] OSHA had lowered the PEL to a STEL of 1 ppm in 1989 under the Air Contaminants Standard.[4] In July 1992, the 11th Circuit Court of Appeals vacated this standard; however, some states operating their own OSHA approved job safety and health programs will continue to enforce the lower limit. OSHA is currently enforcing the 5 ppm limit, but continues to encourage employers to follow the 1 ppm limit. The ACGIH TLV is 3 ppm as an 8-hr TWA, with a STEL of 5 ppm.[5]

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[15-20]

The NIOSH REL for CO is an eight hours per day, 40 hours per week TWA exposure of 35 ppm, and a ceiling limit of 200 ppm.[3] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with carboxy-hemoglobin (COHb) levels in excess of 5%.[15] Currently, the OSHA PEL is 50 ppm as an 8-hr TWA.[4] OSHA had lowered the PEL to 35 ppm, with a ceiling of 200 ppm in 1989 under the Air Contaminants Standard.[4] OSHA is currently enforcing the 50 ppm standard; however, some states operating their own OSHA approved job safety and health programs will continue to enforce the lower limit of 35 ppm. The ACGIH recommends an eight-hour TWA TLV of 25 ppm.[5] In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[21]

Results and Discussion

Engine House 1

The diesel-powered aerial platform truck was moved in and out of the engine house one time on the first night of sampling. No other vehicle starts were recorded by the NIOSH investigators. None of the vehicles in Engine House 1 were moved on the second night of sampling. During the night of June 25-26, 1992, carbon monoxide concentrations measured in Engine House 1 ranged from not detected to 1.9 ppm, well below applicable evaluation criteria. No carbon monoxide was detected in Engine House 1 on the night of June 26-27, 1992. Carbon monoxide results are presented in Table 5. No benzene-solubles were detected in any of the samples collected on either night, except for one sample, collected on the second night, in the large apparatus bay. This 686 minute sample yielded a concentration of 313 $\mu g/m^3$. Since none of the vehicles were moved on the second night, the source of the benzene solubles in this sample is not clear.

Elemental carbon results are presented in Tables 1-4. Personal samples ranged from 51.7 to 71.2 $\mu g/m^3$ on the first night. This is well above the average background elemental carbon concentration of 12.1 $\mu g/m^3$ measured on the first night of sampling. On the second night of sampling, June 26-27, when no vehicle starts were noted by the NIOSH investigators, the results of personal samples for elemental carbon ranged from 14.1 to 21.2 $\mu g/m^3$. The average background elemental carbon concentration measured on the second night of sampling was 8.4 $\mu g/m^3$.

Area samples for elemental carbon on the first night of sampling ranged from 10.2 $\mu g/m^3$ in the kitchen to 167 $\mu g/m^3$ in the large apparatus bay. Area samples on the second night of sampling ranged from 2.21 $\mu g/m^3$ in the large apparatus bay to 18.8 $\mu g/m^3$ in the kitchen.

Engine House 2

On the night of June 25-26, 1992, both the diesel-powered fire truck and the diesel-powered ambulance made one emergency run. On the second night of sampling, June 26-27, the engine made two emergency runs, while the ambulance responded at least five times during the sampling period. Indicator tube sampling conducted while vehicles left or returned to the engine house revealed nitrogen dioxide concentrations that ranged from 0.1 to 0.4 ppm, total oxides of nitrogen (NO_x) in concentrations ranging from 1.4 to 1.7 ppm, and carbon monoxide concentrations of 2 to 3 ppm. No sulfur dioxide was detected using indicator tubes.

Carbon monoxide concentrations measured in Engine House 2 using diffusion tubes ranged from 1.0 to 4.6 ppm on the first night of sampling, and from less than the limit of detection to 1.3 ppm on the second night. These results are much less than the OSHA PEL or NIOSH REL for carbon monoxide. Benzene-solubles ranged from less than the limit of detection to 103 $\mu g/m^3$ on the first night of sampling, and from less than the limit of detection to 313 $\mu g/m^3$ on the second night of sampling.

Elemental carbon results are presented in Tables 1-4. Personal samples ranged from 25.7 to 38.1 $\mu g/m^3$ on the night of June 25-26. These results reflect one response each by the ambulance and fire truck, and are well above the average (of three samples) background elemental carbon concentration of 12.1 $\mu g/m^3$ measured on the first night of sampling. On the night of June 26-27, when the NIOSH investigators noted that the engine made two runs, and that the ambulance responded at least five times, the results of personal samples for elemental carbon ranged from 19.8 to 78.8 µg/m^3. The average background elemental carbon concentration measured on the second night of sampling was 8.4 µg/m^3.

Area samples for elemental carbon on the first night of sampling ranged from 128 µg/m^3 in the kitchen to 823 µg/m^3 in the smoking room, which is located at the rear of the apparatus bay. Area samples on the second night of sampling ranged from 8.51 µg/m^3 in the north dormitory to 355 µg/m^3 in the smoking room.

<u>Engine House 3</u>

On the night of June 25-26, 1992, the firefighters pulled the trucks out of the station to wash them, and drove them back into the station. No other responses were recorded by the NIOSH investigators on that night. On the second night of sampling, June 26-27, two ambulance runs were recorded, and the firefighters drove the trucks out of the station once. Carbon monoxide concentrations measured on the first night of sampling ranged from 0.75 ppm in the dormitory to 1.9 ppm in the kitchen. Concentrations on the second night ranged from a trace amount in the dormitory to 1.1 ppm measured in the hallway. All of these results are far less than the applicable exposure criteria for carbon monoxide. Sampling for benzene solubles did not result in any concentrations in excess of the limit of detection for the method, 0.05 mg per sample, on either night.

Elemental carbon results are presented in Tables 1-4. On the night of June 25-26, the results of personal samples ranged from 24.0 to 35.2 µg/m^3. This is greater than the average background elemental carbon concentration of 12.1 µg/m^3 measured on the first night of sampling, and reflects the exposure associated with the vehicles leaving the station only once. On the second night of sampling, June 26-27, when two ambulance runs were noted, and the vehicles were driven out of the station once, the results of personal samples collected for elemental carbon ranged from 48.0 to 60.5 µg/m^3. The average background elemental carbon concentration measured on the second night of sampling was 8.4 µg/m^3.

Area samples for elemental carbon on the first night of sampling ranged from 17.7 µg/m^3 in the dormitory to 86.4 µg/m^3 in the apparatus bay. Area samples on the second night of sampling ranged from 18.8 µg/m^3 in the kitchen to 204 µg/m^3 in the apparatus bay.

Data obtained from the analysis of nitrogen dioxide samples were inconclusive because the results of blank Palmes Tubes equalled or exceeded field sample results.

Conclusions

When diesel-powered equipment leaves or returns to an engine house, exhaust emissions containing diesel particulate are produced inside the apparatus bay. The diesel exhaust can enter the living quarters. Limited epidemiological evidence suggests an association between occupational exposure to diesel exhaust emissions and lung cancer.[13] The agreement of current toxicological and epidemiological evidence suggests that occupational exposure to diesel exhaust is a potential carcinogen.[10]

Engineering controls and work practices are needed to reduce the potential risk to firefighters from diesel exhaust emission exposures. Several control options are available for the control of diesel exhaust emissions from these vehicles. Three potentially effective engineering control options are presented in the recommendations section of this report, but other control solutions may be effective. The three options are engine exhaust filters, tailpipe local exhaust ventilation, and dilution ventilation. Work practices also can be implemented to curtail the amount of diesel fumes emitted into the fire station.

The engineering controls and work practices provided in this report represent prudent practice for the reduction of diesel particulate emissions and diesel particulate exposures to firefighters. With a few exceptions, the efficacy of control options discussed here have not been documented; therefore, no recommendation can be made as to which control option is best nor can conclusions be made as to the percentage reduction or the ultimate exposure level that may be achieved by using a particular control or combination of controls.

In 1988, EPA began issuing diesel particulate emission standards for heavy duty diesel-powered equipment such as buses and fire trucks. Reductions in emissions levels were ordered in 1991 and a final level for 1994. The 1994 standard requires that heavy duty diesel vehicles emit no more than 0.1 gram per brake horsepower per hour (gm/bhp/hr) of diesel particulate.[24] This represents about a 90 percent reduction from uncontrolled diesel exhaust particulate levels. In the long run, implementation of this EPA standard will achieve a major reduction in diesel particulate levels for firefighting vehicles; however, since diesel equipment typically lasts 15 to 20 years, control options such as those discussed above need to be applied in the interim.

Recommendations

A. Engineering Controls

1. Engine exhaust filters

   Engine exhaust filters are designed to remove particulate from the exhaust stream. The filters are installed in the exhaust system or at the tailpipe. One commercially available filter system consists of a porous ceramic filter, a diverter valve, and an electronic control module. The diverter valve is installed in the exhaust pipe and directs the exhaust through the ceramic filter when the engine is started. After a preset time, usually between 20 seconds and 3 minutes, the electronic control vents the exhaust to the exhaust pipe, bypassing the ceramic filter. The timer should be set to allow enough time for the truck to exit the fire station. When the truck is shifted into reverse to back into the garage, the electronic control again routes the exhaust fumes through the filter. The ceramic filter weighs between 20 and 30 pounds and collects about 2 pounds of particulate before requiring servicing. The approximate cost for one filter system is $10,000 (1993).[22]

   A report by researchers at the U.S. Bureau of Mines showed that the ceramic filter reduced diesel particulate concentrations by at least 90 percent on a load-haul-dump vehicle in a mine.[23] No documentation on the performance of the ceramic filter specifically for diesel-powered fire trucks was found in the literature; however, a number of local fire chiefs have written letters to the manufacturer of the filter system testifying to the good performance of the ceramic filter in reducing the diesel emissions from fire trucks.

Another version of the particulate filter, a filter trap, developed by the Donaldson Company in Minnesota, reduces diesel particulate levels by 80+ percent. The current cost of this filter trap is about $15,000.[24]

2. Local tailpipe exhaust ventilation

A local exhaust ventilation control for diesel particulate emissions from fire trucks while in the fire station is the tailpipe exhaust hose (also called an exhaust extractor). A hose attaches to the tailpipe and connects to a fan which discharges the diesel exhaust to the outside. One manufacturer of these controls recommends an exhaust rate of 600 cubic feet per minute (cfm) for each vehicle. The hoses can be purchased with several options. One is an automatic disconnect feature which automatically disconnects the hose from the vehicle exhaust pipe as the vehicle pulls out of the garage. Another option is to install an overhead rail to keep hoses off of the floor. The hoses are suspended from the rail by a balancer that automatically retracts the hose when it is not in use. Various hose diameters are available for different size exhaust pipes. Costs will vary with length of hose, type of overhead mounting, and with the number of options purchased.

An advantage of the tailpipe exhaust hose is that it also removes gaseous emissions in the diesel exhaust such as nitrous oxides and sulfur oxides. The tailpipe exhaust hose captures the exhaust emissions when the vehicle exits the fire station but affords no control when the vehicle reenters the station, unless the exhaust hose is reattached to the fire truck in the driveway.

3. Dilution ventilation

With dilution ventilation, the air contaminated with diesel fumes is exhausted to the outside while fresh outside makeup air flows into the garage through open doors or supply air openings. Air is exhausted using a roof or wall fan. The exhaust airflow rate and the time required to remove 85 percent of the contaminated air can be calculated from standard ventilation equations.[25] At Engine House 1, a fan delivering 5000 cfm can remove 85 percent of the contaminated air in 20 minutes assuming good mixing of the fresh air with the air in the garage (Table 6). The time needed to remove 85 percent of the air in the garages using a 5000 cfm fan at Engine Houses 2 and 3 are also shown in Table 6. Keeping the garage doors open during this period should allow for good mixing. The fan can be integrated into the fire alarm system so that it turns on before the fire trucks are started. It may also be worthwhile to turn the fan on for a few minutes after the fire trucks have returned to the garage. The major drawback to using dilution ventilation is the cost of heating the makeup air during the cold weather months in Ohio.

The exhaust fan should be located toward the rear of the fire station garage opposite the garage doors so that outside air flows through the open garage doors, sweeping the entire length of the building before being exhausted. At Engine House 1, two fans may be best, a larger fan for the older building and the other for the garage annex. At Engine Houses 2 and 3, exhaust fans may be located in the roof or in one of the high windows in the wall. The exhaust fans should be located high in the wall (or in the ceiling) and at the opposite end of the garage from the garage doors. If the garage doors cannot be kept open while the exhaust fan is running, a supply air fan located at the opposite side of the building from the exhaust fan can be installed to bring fresh air into the garage.

4. Other

Important information on controlling diesel exhaust emissions in fire stations is found in Attachment 1, a bulletin prepared by the New Jersey Public Employees Occupational Safety and Health Program (PEOSH).[26] The brochure entitled "Diesel Exhaust in Fire Stations" includes engineering control options such as modifying the weatherstripping on all doors leading from the garage to the offices and living quarters to prevent infiltration of diesel fumes. Another recommendation is to keep the living quarters under positive pressure to prevent entry of fumes.

B. Work Practices

In addition to engineering controls, improved work practices may help reduce diesel emissions and subsequent personal exposures to diesel particulate. Some examples which are mentioned in the PEOSH brochure include (1) always open the garage doors before vehicles are started; (2) keep fire engine operation inside the garage to an absolute minimum; and (3) keep doors between the garage and other areas of the firehouse closed. Other work practices include regular engine maintenance to minimize diesel particulate emissions.

Another approach that may accelerate the trend toward lower diesel particulate emissions is a retrofit program that is being tried by one diesel engine manufacturer. When diesel engines require major overhauls, they are rebuilt so that considerably less diesel particulate is generated.

References

1. NIOSH [1992]. NIOSH comments to DOL: comments from the National Institute for Occupational Safety and Health on the Mine Safety and Health Administration proposed rule on permissible exposure limit for diesel particulate. July 10, 1992. NIOSH policy statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

2. NIOSH [1984]. Eller PM, ed. NIOSH manual of analytical methods. 3rd rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

3. NIOSH [1992]. NIOSH recommendations for occupational safety and health, compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

4. OSHA [1989]. Air contaminants - permissible exposure limits (Title 29 Code of Federal Regulations Part 1910.1000). Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration. OSHA Publication No. 3112.

5. ACGIH [1992]. Threshold limit values and biological exposure indices for 1992-1993. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

6. Linnell RH, Scott WE [1962]. Diesel exhaust composition and odor studies. J Air Pollut Control Assoc 12:510-545.

7. Environmental Health Associates [1978]. Health effects of diesel exhaust emissions. Berkeley, CA.

8. Schenker [1980]. Diesel exhaust--an occupational carcinogen? J Occup Med 22:41-46.

9. Travis CC, Munro NB [1983]. Potential health effects of light-duty diesel exhaust. Risk Analysis 3:147-155.

10. NIOSH [1988]. Current intelligence bulletin 50: Carcinogenic effects of exposure to diesel exhaust. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 88-116

11. Weisenberger [1984]. Health effects of diesel emissions--an update. J Soc Occup Med 34:90-92.

12. Cuddihy RG, Griffith WC, McClellan RO [1984]. Health risks from light-duty diesel vehicles. Environ Sci Technol 18:14A-21A.

13. Garshick E, Schenker MB, Munoz A, Segal M [1988]. A retrospective cohort study of lung cancer and diesel exposure in railroad workers. Am Rev Resp Dis 137:820-825.

14. Hathaway GJ, Proctor NH, Hughes JP, Fischman ML [1991]. Proctor and Hughes' chemical hazards of the workplace. 3rd. ed. New York, NY: Van Nostrand Reinhold Company, pp. 432-434.

15. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000.

16. NIOSH [1977]. Occupational diseases - a guide to their recognition. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHEW(NIOSH) Publication No. 77-181.

17. NIOSH [1979]. A guide to work-relatedness of disease. Revised Ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHEW (NIOSH) Publication No. 79-116.

18. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical Hazards of the Workplace. Philadelphia, PA: J.B. Lippincott Company.

19. ACGIH [1986]. Documentation of threshold limit values and biological exposure indices (with 1990 supplements). 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

20. NIOSH [1990]. Pocket Guide to Chemical Hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 90-117.

21. National Research Council [1985]. Emergency and continuous exposure guidance levels for selected contaminants. Washington, D.C.: National Academy Press.

22. Ward Diesel Filter Systems, Inc. No smoke exhaust filtration. Elmira Heights, New York.

23. Baumgard KJ [1986]. Estimation of diesel particulate matter reductions in underground mines resulting from the use of a ceramic particle trap. Annals of the American

Conference of Governmental Industrial Hygienists 14:257-263.

24. Carlson P [1993]. Telephone conversation on February 8, 1993, between P. Carlson, U.S. Environmental Protection Agency, and J. Sheehy, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

25. IVE Inc. [1991]. Industrial Ventilation Work Book, 2nd ed., Salt Lake City, UT: IVE Inc.

26. New Jersey Department of Health [1986]. Diesel exhaust in fire stations. Trenton, NJ: New Jersey Department of Health, Public Employees Occupational Safety and Health Program.

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Copies of this report have been sent to:

1. Chief, Division of Fire, City of Lancaster, Ohio
2. President, IAFF Local 1745
3. IAFF International Office of Health and Safety
4. OSHA, Region V

For the purpose of informing affected employees, 42 CFR 85.11 requires the employer to post a copy of this report at or near the workplace(s) of affected employees for a period of 30 calendar days.

Table 1
Results of Personal Breathing Zone Air Samples for Elemental Carbon
City of Lancaster, Division of Fire
Lancaster, Ohio
June 25-26, 1992
HETA 92-0160

Job Title	Sample Duration (minutes)	Sample Volume (liters)	Concentration (micrograms/cubic meter)
	Engine House 1		
Fire Fighter	663	1227	71.1
Fire Fighter	661	1256	51.7
Ca	662	1225	71.2
Engine House 2			
Fire Fighter	583	1166	38.1
Medic/Fire Fighter	582	1135	29.8
Lieutenant	581	1133	25.7
Engine House 3			
Fire Fighter	818	1636	24.0
Medic/Fire Fighter	700	1330	27.0
Lieutenant	814	1628	35.2

The average elemental carbon concentration measured outside of the three engine houses on June 25-26, 1992 was 12.1 micrograms/cubic meter.

Table 2
Results of Personal Breathing Zone Air Samples for Elemental Carbon
City of Lancaster, Division of Fire
Lancaster, Ohio
June 26-27, 1992
HETA 92-0160

Job Title	Sample Duration (minutes)	Sample Volume (liters)	Concentration (micrograms/cubic meter)
Engine House 1			
Fire Fighter	716	1289	18.1
Fire Fighter	715	1287	14.1
Lieutenant	722	1300	21.2
Engine House 2			
Fire Fighter	583	1108	32.3
Medic	295	546	78.8
Lieutenant	629	1227	19.8
Engine House 3			
Medic Trainee	741	1445	60.5
Medic Trainee	735	1397	52.8
Office	779	1519	48.0

The average elemental carbon concentration measured outside of the three engine houses on June 26-27, 1992 was 8.4 micrograms/cubic meter.

Table 3
Results of General Area Air Samples for Elemental Carbon
City of Lancaster, Division of Fire
Lancaster, Ohio
June 25-26, 1992
HETA 92-0160

Location	Sample Duration (minutes)	Sample Volume (liters)	Concentration (micrograms/cubic meter)
Engine House 1			
Kitchen	633	1171	10.2
Large Apparatus Bay	490	931	167
Small Apparatus Bay	626	1158	144
TV Room	621	1211	51.5
Dormitory	618	1174	33.5
Engine House 2			
Kitchen	582	1106	128
Apparatus Bay	605	1180	683
North Dormitory	610	1190	435
South Dormitory	607	1184	131
Smoking Room	588	1117	823
Engine House 3			
Kitchen	792	1584	24.3
Apparatus Bay	787	1574	86.4
Dormitory	794	1548	17.7
Hallway	776	1552	67.2

The average elemental carbon concentration measured outside of the three engine houses on June 25-26, 1992 was 12.1 micrograms/cubic meter.

Table 4
Results of General Area Air Samples for Elemental Carbon
City of Lancaster, Division of Fire
Lancaster, Ohio
June 26-27, 1992
HETA 92-0160

Location	Sample Duration (minutes)	Sample Volume (liters)	Concentration (micrograms/cubic meter)
Engine House 1			
Kitchen	694	1215	18.8
Large Apparatus Bay	686	1269	2.21
Small Apparatus Bay	681	1260	11.7
TV Room	698	1361	5.83
Dormitory	703	1265	11.0
Engine House 2			
Kitchen	697	1290	26.0
Apparatus Bay	693	1317	327
North Dormitory	702	1334	8.51
South Dormitory	690	1344	27.5
Smoking Room	688	1342	355
Engine House 3			
Kitchen	821	1601	18.8
Apparatus Bay	818	1554	204
Dormitory	814	1547	42.2
Hallway	820	1517	177

The average elemental carbon concentration measured outside of the three engine houses on June 26-27, 1992 was 8.4 micrograms/cubic meter.

Table 5
Results of General Area Air Samples for Carbon Monoxide
City of Lancaster, Division of Fire
Lancaster, Ohio
June 25-27, 1992
HETA 92-0160

Location	Sample Duration (minutes)		Concentration (parts per million)	
	June 25-26	June 26-27	June 25-26	June 26-27
Engine House 1				
Kitchen	638	693	1.9	ND
Large Apparatus Bay	632	686	ND	ND
Small Apparatus Bay	620	681	0.97	ND
TV Room	613	698	ND	ND
Dormitory	607	708	ND	ND
Engine House 2				
Kitchen	579	697	3.1	ND
Apparatus Bay	601	693	2.8	1.3
North Dormitory	608	701	2.2	ND
South Dormitory	604	---	0.99	ND
Smoking Room	586	---	4.6	ND
Engine House 3				
Kitchen	786	821	1.9	0.73
Apparatus Bay	779	818	1.2	0.73
Dormitory	795	814	0.75	ND
Hallway	773	822	1.6	1.1

--- indicates that no sample was collected in this area. ND indicates that results were less than the limit of detection. The manufacturer reports that the range of measurement is 50 to 600 ppm hours, or 3.6 ppm for a maximum sampling time of 822 minutes in this sampling set. Results less than this amount should be regarded as trace concentrations, with limited confidence in their accuracy. The NIOSH REL for CO is an eight hours per day, 40 hours per week TWA exposure of 35 ppm, and a ceiling limit of 200 ppm.[3] Currently, the OSHA PEL is 50 ppm as an eight hour TWA.[4] The ACGIH recommends an eight-hour TWA TLV of 25 ppm.[5] In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[21]

Table 6
Amount of Time Needed to Exhaust 85 Percent of the Air in an Engine House Garage.
City of Lancaster, Division of Fire
Lancaster, Ohio
HETA 92-0160

Engine House	**Garage Volume** (cubic feet)	**Exhaust Fan Capacity** (CFM)	**Time** (minutes)
1	35,900	5000	20
2	23,000	5000	13
3	33,600	5000	19

DIESEL EXHAUST IN FIRE STATIONS

NEW JERSEY DEPARTMENT OF HEALTH

INFORMATION BULLETIN

September, 1986

INTRODUCTION

In the course of fighting a fire, firefighters may be exposed to a variety of toxic air contaminants. Concern has been expressed that fire fighters may also be exposed to toxic air contaminants in fire stations from diesel exhaust from fire trucks. This information bulletin will supply information on diesel exhaust and make recommendations for controlling exposure to diesel exhaust in fire stations.

When diesel fire trucks leave the fire station, the exhaust generated can spread to the living quarters, where in addition to its toxic effects it can darken walls and settle on food and clothing. It also can have an unpleasant odor.

COMPONENTS OF DIESEL EXHAUST

In the last ten years there has been considerable interest in the potential adverse health effects from exposure to diesel engines emissions. In considering the potential health effects arising from exposure to diesel exhaust, it is helpful to view the exhaust as being composed of two phases, gaseous and particulate. The gaseous phase of diesel exhaust is composed of carbon monoxide, oxides of sulfur and nitrogen, and unburned or partially burned hydrocarbons.

Diesel engines also emit particulates, in an amount 50 to 80 times greater than gasoline powered vehicles. These particulates are small in size, easily inhaled and they contain a myraid of different chemicals adsorbed on their surfaces, that typically represent 15-65% of the mass of the particles. The remainder of the particles are made of carbonaceous material. One group of chemicals found on diesel particulates are polynuclear aromatic hydrocarbons (PAH). Typically, benzo(a)pryene, benz(a)anthracene, benzo(e)pyrene, chrysene, pryene, anthracene, fluoranthene, and phenanthrene are common PAH compounds of potential toxicological significance identified in exhaust emissions.

HEALTH EFFECTS

Concern regarding diesel particulates arises because many of the species of PAHs listed above have been demonstrated to be carcinogenic or co-carcinogenic . There is evidence that there is an increased risk of lung cancer firm exposure to diesel exhaust. However, much of the work in this area is preliminary and further research is needed.

EXPOSURE LEVELS

A study assessing the exposures levels of fire fighters to diesel exhaust has been conducted (1). Personal sampling techniques were used to evaluate firefighter exposure to particulates from diesel engine emissions. Fire stations in New York, Boston, and Los Angeles were studied. A positive relationship between the number of alarm responses and the concentration of total particulate was observed. When there were between 7 and 15 alarms during an 8 hour shift, resulting exposure levels of total airborne particulate from diesel exhaust ranged from 100-300 ug/m^3 (micrograms per cublic meter of air) averaged over eight hours.

To understand the significance of these levels they can be compared to ambient air levels. In New York and Boston, ambient air measurements for particulates during this study ranged from 30 to 60 ug/m^3.

It should be noted that the particulate levels quoted above are outdoor levels and are expected to be composed of a variety of particulates. The particulate levels measured in firehouses would probably contain a higher percentage of particulates from diesel exhaust, and therefore a higher percentage of PAH's.

RECOMMENDATIONS TO CONTROL EXPOSURE

Particulates from diesel exhaust in firehouses can exceed background (ambient) levels. Since diesel exhaust potentially presents some carcinogenic risk, it is important to minimize the exposure of firefighters time.

Examples of ways to control diesel exhaust emissions in firehouses are outlined below. These probably are not the only ways to control diesel exhaust and it may be necessary to use more than one method.

Work Practices

1. The garage doors should be opened before the engines of the vehicles are started and the vehicles should not be allowed to idle in the firehouse.
2. All drivers should be instructed to keep vehicular operation to an absolute minimum within the firehouse.
3. Garage doors should be left open, whenever weather conditions permit, for at least 10 minutes following the operation of the vehicles.

(1) Froines, J., W. Hinds, R. Duffy, E. LaFuente and L. Wen-Chen: Exposure of Firefighters to Diesel Emissions in Fire Stations. American Industrial Hygiene Association Journal. 48(3):202-207 (1987).

New Jersey State Department of Health
Division of Occupational and Environmental Health • Occupational Health Service
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4. A procedure should be established and enforced to keep doors leading directly from the garage to other areas of the firehouse closed whenever possible. Consideration should be given to installing automatic door closers where appropriate.

Engineering Controls

1. All doors leading from the garage to stairwells, hose towers, living quarters, kitchen or office should be modified by the addition of weather stripping (on similar material) in order to prevent diesel exhaust infiltration.

2. All pole holes that are not essential should be permanently sealed. Active pole holes should have flexible covers with air tight seals. An alternative is to install air tight booths.

3. Ventilation should be installed to control exhaust:

   (a) Hot exhaust emissions rise, therefore, exhaust fans should be located near the ceiling.

   (b) The volume of exhaust emissions generated is dependent on the number of trucks in the firehouse and the horsepower of the trucks. The American Conference of Governmental Industrial hygienists recommends a dilution ventilation rate for 100 cubic feet per minute (cfm) per horsepower for diesel engines that are idling.

   (c) Make-up air must be supplied to replace air exhausted by the fan.

   (d) The exhaust should be situated to prevent re-entry of exhaust through windows or fresh air intakes.

4. The City of Los Angeles Fire Department has found the following procedures useful in reducing diesel apparatus emissions. These procedures should be used when appropriate within the existing maintenance program:

   (a) Additives can be placed in diesel fuel tanks to combat water, sludge and algae.

   (b) Injectors which are subject to continual problems, such as plugging and high emissions should be changed. This is done after all other sources of fuel contamination are eliminated.

   (c) The Los Angeles Fire Department now specifies a particular engine when purchasing new apparatus based on mechanical performance and diesel emissions. It is recommended that both mechanical performance and emissions data be included as primary criteria for engine selection. In this respect, it must be remembered that exposure to diesel exhaust occurs both enroute to and returning from the fire scene.

5. Infiltration of exhaust can be reduced by maintaining living quarters and office areas under positive pressure and keeping doors to contaminated area closed whenever possible. Window mounted air conditioners or fans which bring fresh outside air into these areas will assist in this process. This will also improve indoor air quality by providing at least a minimum supply of fresh air (i.e. 5 cubic feet per minute per person) at all times. A positive pressure of about 0.03 to 0.05 inches of water gauge is recommended (approximately equal to an 8 mph wind) to prevent infiltration of exhaust. The PEOSH program can provide additional information on maintaining indoor air quality as required.

Further information may be obtained by calling the Public Employees Occupational Safety and Health Program at (609) 984-1863.

*800291

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Division of Occupational and Environmental Health
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FIGURE 1

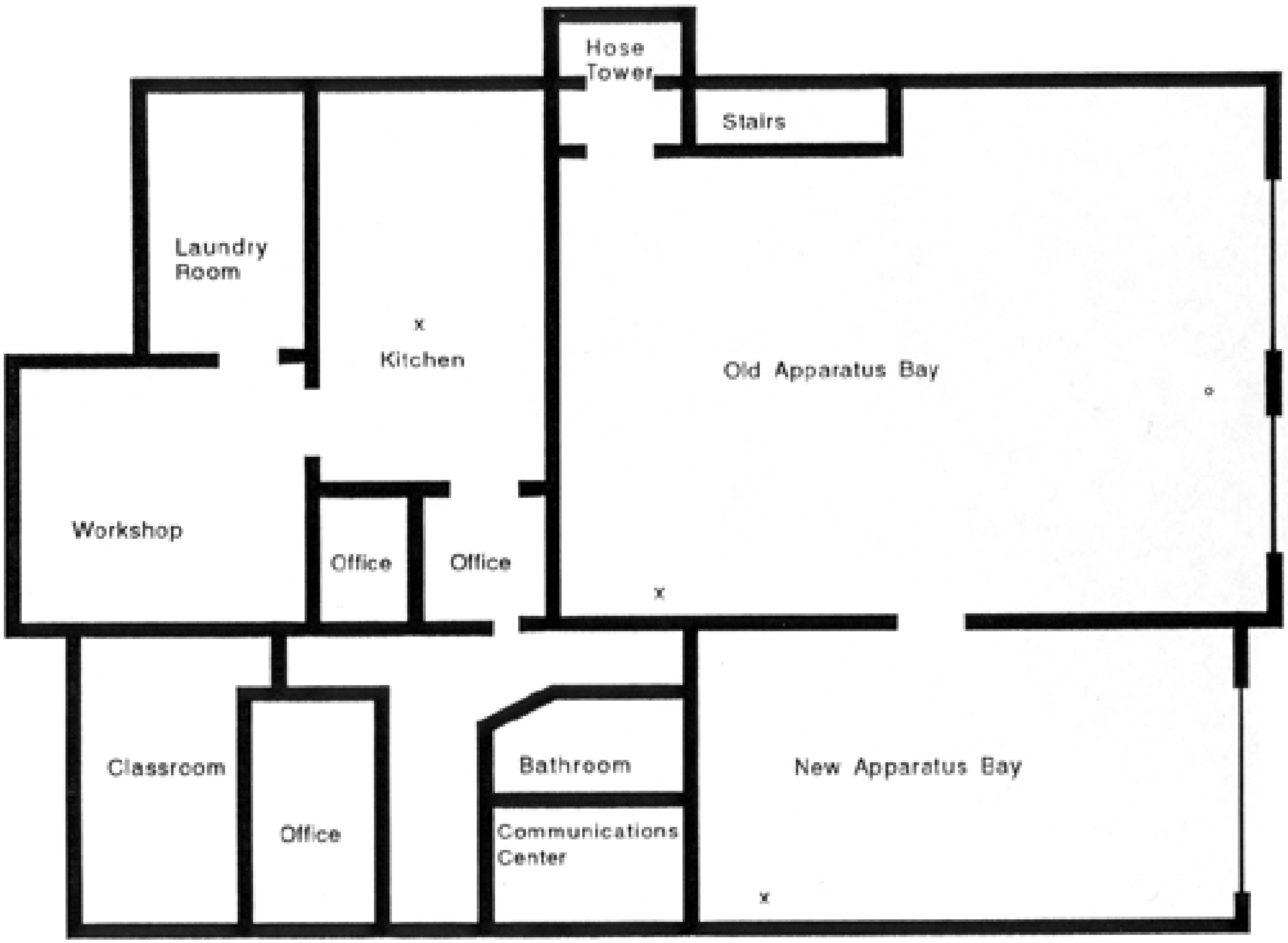
First Floor, Engine House 1

City of Lancaster, Division of Fire

Lancaster, Ohio

June 25-27, 1992

HETA 92-0160



Sampling Locations Are Marked With an X

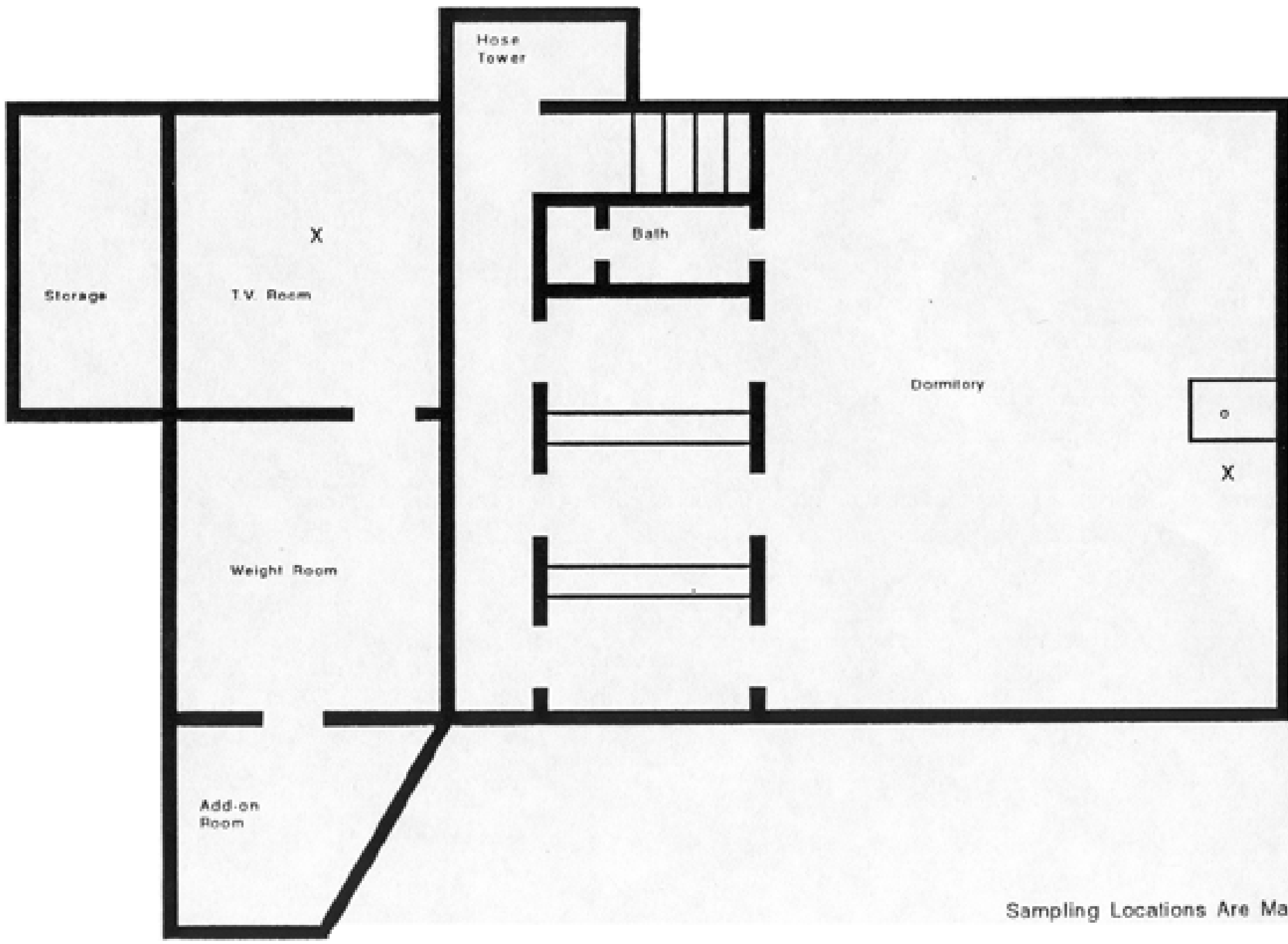
FIGURE 2
Second Floor, Engine House

City of Lancaster, Division of Fire

Lancaster, Ohio

June 25-27, 1992

HETA 92-0160



Sampling Locations Are Marked With an X

FIGURE 3

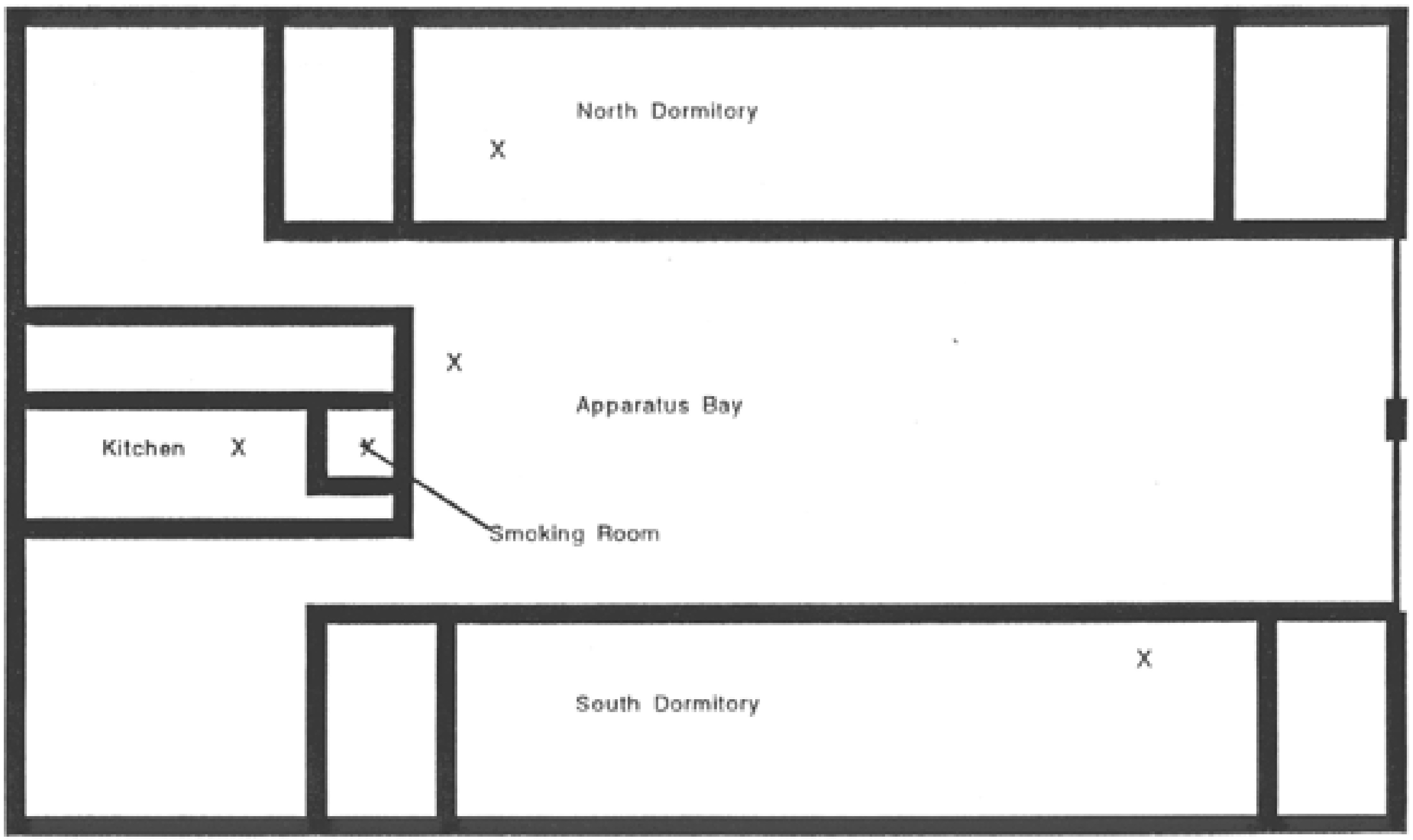
Engine House 2

City of Lancaster, Division of Fire

Lancaster, Ohio

June 25-27, 1992

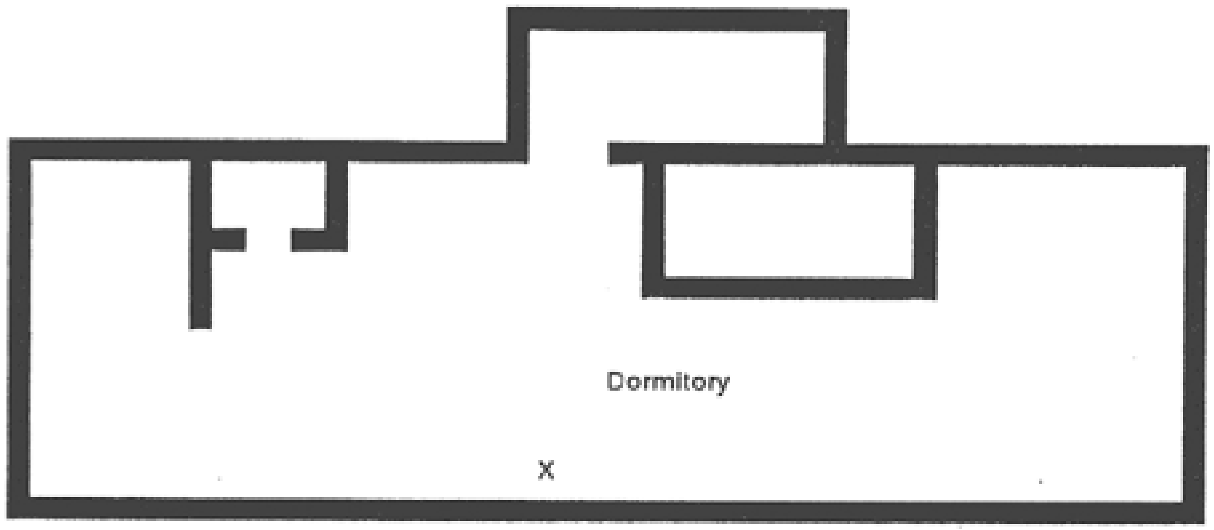
HETA 92-0160



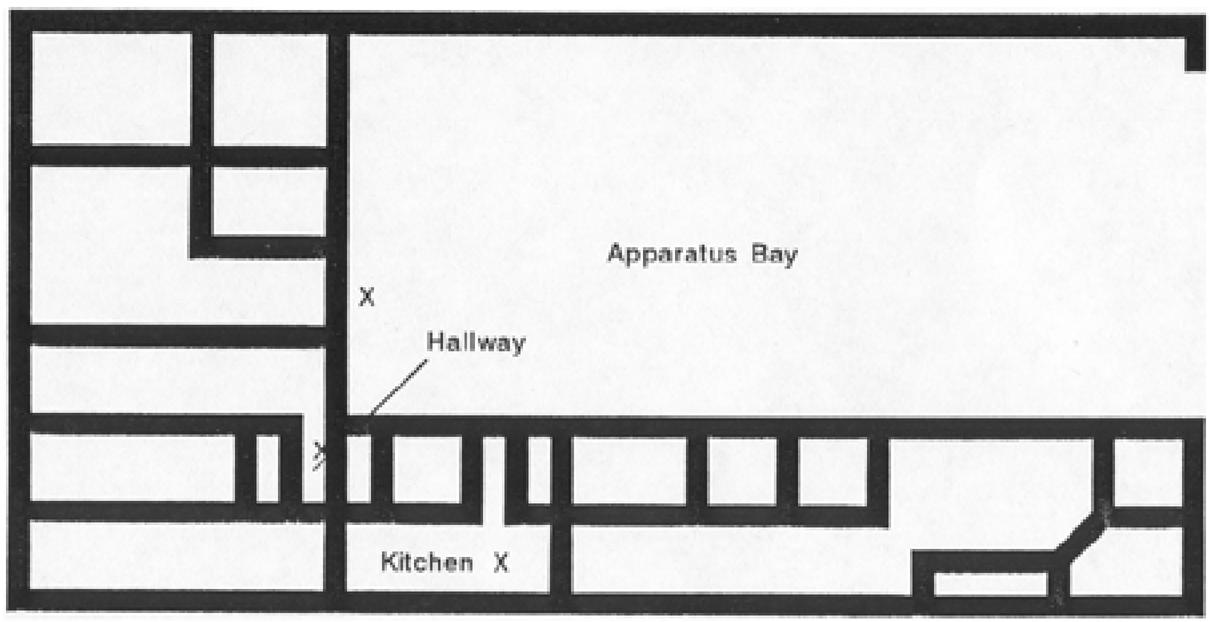
Sampling Locations Are Marked With an X

FIGURE 4

Engine House 3
City of Lancaster, Division of Fire
Lancaster, Ohio
June 25-27, 1992
HETA 92-0160



Second Floor



First Floor

Sampling Locations Are Marked With an X